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M. Rey Porto, T. Carretero, M. Aguado, R. Garde

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H₂ Production in Sotavento Wind Farm

Milagros Rey Porto, Trinidad Carretero, Gas Natural SDG S.A., Plaça del Gas 1, 08003 Barcelona, Spain

Mónica Aguado, Raquel Garde, Renewable Energy Grid Integration Department, National Renewable Energy Centre (CENER), Ciudad de la Innovación, 7, 31621 Sarriguren, Spain

Summary

This article aims to show a hydrogen production and conversion plant from wind power, the biggest of Spain, owned by Gas Natural.

1 Background

For decades, a series of progressive decrease in the reserves of fossil fuels and environmental problems associated with burning them have promoted the search for alternative energy, including renewable energies (EERR).

The use of EERR offers numerous advantages. The main ones include:

- They are inexhaustible
- Both production and consumption of energy are major emitters of greenhouse gases. The use of renewable energy, allows producing a low environmental impact.
- Statewide, they foster the decline of foreign energy dependence by providing a diversification of energy sources
- Contribute to improve and modernize the industrial base, the generation of employment and, therefore, regional development
- Distributed Generation Systems allows the point of generation being close to the consumption, and therefore to reduce electricity losses produced in transport and the necessity of transportation infrastructure.

Faced with all these advantages, the EERR have three major drawbacks:

- The great variability of renewable resources
- The difficulty of the production
- The difficulty of adjusting production to demand

Currently in Spain there are over 16,500 MW installed, this means a coverage greater than 12% of electricity demand.

Given the magnitude of wind power installed and the expected growth in the coming years, it is very important to mitigate and correct the weaknesses of wind power. It becomes imperative to manage the energy produced into the grid by wind turbines. Therefore, it is necessary to research and develop technologies to correct the variability of the resource and adjust the production to demand.

These technological developments are focused on the prediction and storage of wind power delivered to the grid.

The resolution of the problem of electricity storage on a large scale is one of the most important technological challenges to overcome in the field of electrical engineering. Currently there are various storage systems based on the amount of stored energy and storage time needed [1].

Energy storage can solve most problems associated with wind power:

1. The energy generated by wind farms is allowed to be managed, improving its selling price in the pool [2].
2. Wind energy production is possible to be adjusted to forecasts predictions as well as get a guarantee of wind production at peak electricity demand
3. The penetration level of wind power is allowed to be increased, once it becomes manageable. Using these systems the installed capacity could be increased in resource-rich sites: during times of high wind, wind power is stored, so the limit of the network is never reached and electricity is injecting into the grid in times of low wind production [3,4,5]
4. Allows implementing wind farms in remote locations but with high potential, reducing transmission costs.

2 Hydrogen as Storage System

This article presents an installation that utilizes the technology of H_2 as energy storage system.

The concept of generating H_2 from wind born in 1923, when John BS, Haldane proposed the production of H_2 and O_2 from water using this type of energy [6]. Back in the 30s Hermann Honnef introduced the use of high-power wind turbines to generate H_2 . [7] From the 60s is beginning to study the electrolysis using solar power and extend the studies of H_2 generation from wind energy. [8, 9, 10, 11]

Hydrogen is an energy carrier, in other words there is no free in nature and must be obtained from a primary source, although there are numerous sources and hydrogen production technologies.

Thus, hydrogen is one of the energy carriers with greater environmental benefits because its combustion produces no emissions and its production will have a greater or lesser environmental impact in terms of the energy that is used to generate it.

Therefore, if obtained through renewable energy, the environmental impact it causes is minimal. It is for this reason that today there is great interest in developing projects that use hydrogen generated from renewable energy as energy storage.

The development of such facilities in each country is conditioned by the quality of the transport and distribution grid and existing legislation in terms of renewable energy and management.

Currently, there are two types of systems that use H_2 as energy storage of wind power. The former are island energy systems, whose primary objective is to satisfy the demands of a particular community with an island configuration of the grid. The others are integrated energy systems in the electrical grid, which aim to manage and optimize energy production from a wind farm, improving their capacity factor. Both approaches must be addressed from

different perspectives, because the objectives, and therefore the operation mode of the facility, are different.

Another objective of such facilities is the generation of H_2 as fuel using renewable sources instead of conventional natural gas reforming.

At present, there is some development of the study of such systems. In fact, the facilities currently available are directed mostly to study energy self-sufficiency of communities in island or the production of H_2 as fuel.

However, the installation presented here is one of the largest global capacity, where hydrogen is used in the energy management of the production of a wind farm. Therefore, it could be used as a platform for the development of tests and studies in this type of facility.

3 Sotavento Wind Farm

The facility is located in the Sotavento wind farm in the municipality of Xermade (Lugo), at its border with the municipality of Monfero (A Coruña). This has a rated capacity of 17.56 MW with 24 wind turbines of 5 different technologies (Figure 1).

This project was born thanks to a framework agreement between Gas Natural and the Department of Innovation, Industry and Trade of the Xunta de Galicia for the development of renewable energy. In 2008 an agreement with the National Renewable Energy Center (CENER) was signed by Gas Natural to study, analyze and characterize the plant.

The facility uses the surplus electricity generated by the wind farm, in other words the excess of energy produced over than expected to generate hydrogen with an electrolyser. This breaks down water using electricity (electrolysis) in four stacks of electrolytic cells, generating separate H_2 and O_2 .

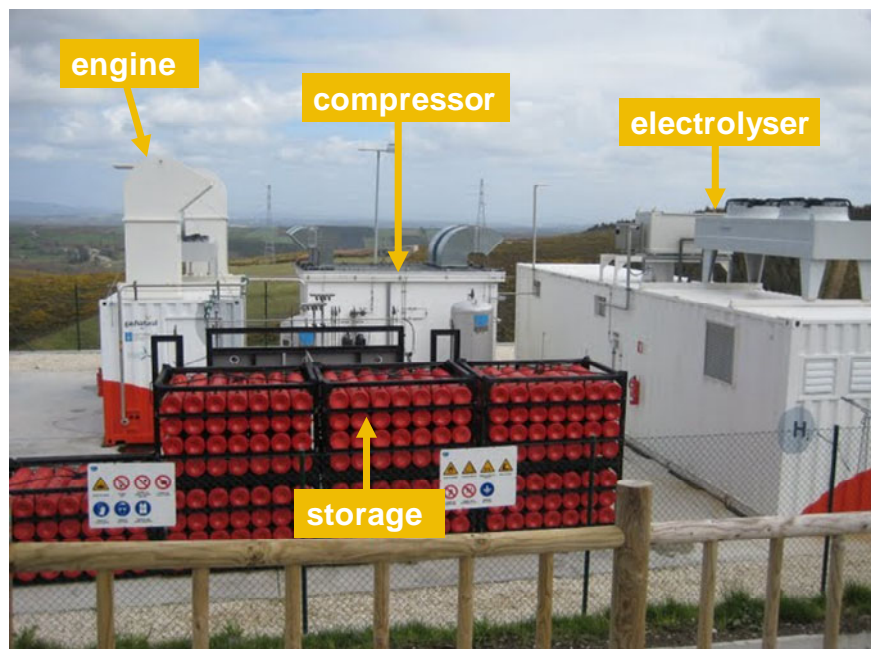


Figure 1: Photography of the H_2 facility.

Figure 2 contains the main equipments of this installation: electrolyser, compressor, H₂ storage and H₂ engine.

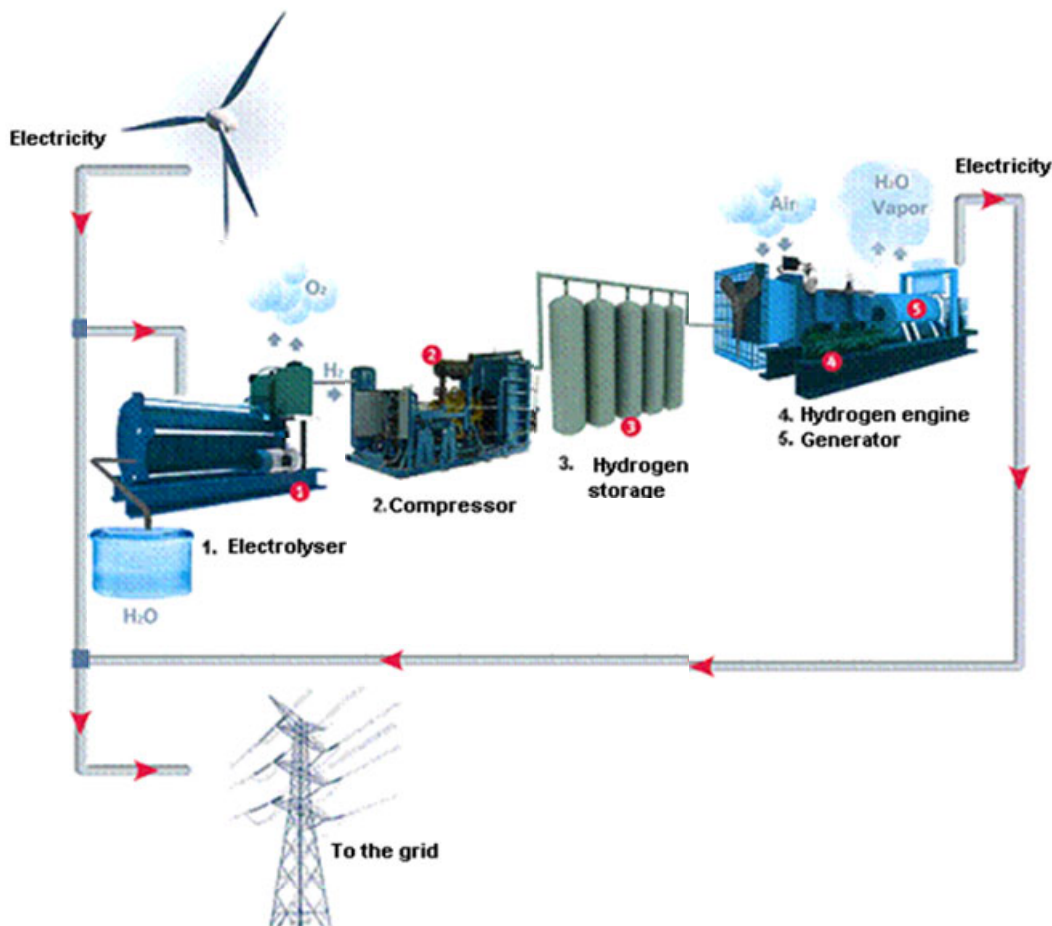


Figure 2: Scheme of the H₂ facility.

The O₂, that is not going to be used in this process is vented to the air and the H₂, produced at a rate of 60 Nm³/h and a pressure of 10 bar, goes through a process of purification and drying to obtain a purity higher than 99.99%.

To increase storage capacity, the H₂ generated is compressed to 200 bar in two compressor groups supporting up to 61.8 Nm³/h at 4 bar.

The storage system at 200 bar is composed by 7 blocks of 28 bottles each, with a maximum capacity of 1.725 Nm³. These blocks are interconnected forming two groups of H₂ storage, with the possibility of isolation of each group.

The H₂ stored can be used in a 55 kW engine in case of energy deficit, that is, if the amount of energy produced by wind turbines in the wind farm is less than that is expected to generate.

The engine has a consumption of up to 70 Nm³/h of H₂ at a pressure of 25-60 mbar H₂. The compressed H₂ at 200 bar, is decompressed in a first stage to 14 bar and a second until the suction pressure of engine.

The electrolyser Hydrogenics is mounted in a container consisting of three separate rooms: the process plant, control room and electric power and ancillary items room.



Figure 3: Photograph of the exterior of the electrolyser.

There are four cell stacks in the process plant. These consist of a series of interconnected electrolytic cells. Each contains the cathode, the anode and an inorganic ion-exchange membrane (patented technology IMET). The membrane prevents contact and reaction between O_2 and H_2 produced in the electrodes. As electrolyte is used a basic aqueous solution of KOH 30%. The process occurs at a pressure of 10 bar.

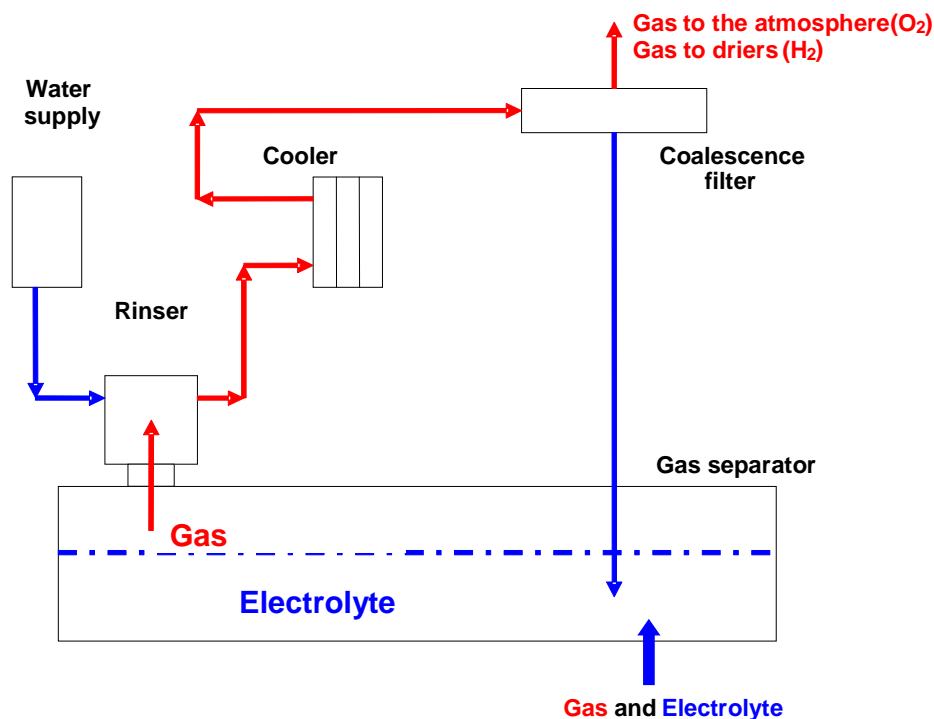


Figure 4: Operating diagram of the electrolyser.

The control room contains the electrical board; two closets EPS (Electrolyser Power Supply) and the control system of the unit.

The electrolyser power system comprises four AC to DC converters. Those four converters are grouped two to two and are fed by two lines.

All components of the compression plant are located inside a soundproof booth for outdoor installation, with ventilation and heating system. The piston compressor has of two groups Bauer Model HFS 15.4-13-DUO II.



Figure 5: Photography inside the compressor.

The motor-generator Continental Energy Systems of 55 kW, which uses hydrogen as fuel, is mounted on rigid base structure and has a radiator for heat dissipation, gas pipeline and control system. The H₂ engine consumes a maximum rate of 70 Nm³ H₂/h. The whole team is in a soundproof container.

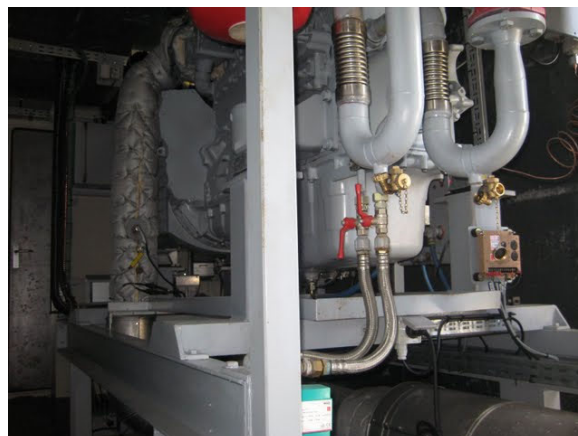


Figure 6: Photography inside the motor-generator group.

Each system has its own control system. In this project we have developed an integrated communications system. We use MODBUS as communication protocol and integrate signals from the engine, compressor, electrolyser and network into a common server.

The control system has a visualization software that allows the sending of orders by the operator and displaying the status of all equipment and variables involved in the operation of the facility. In addition, there is an acquisition of historical data.

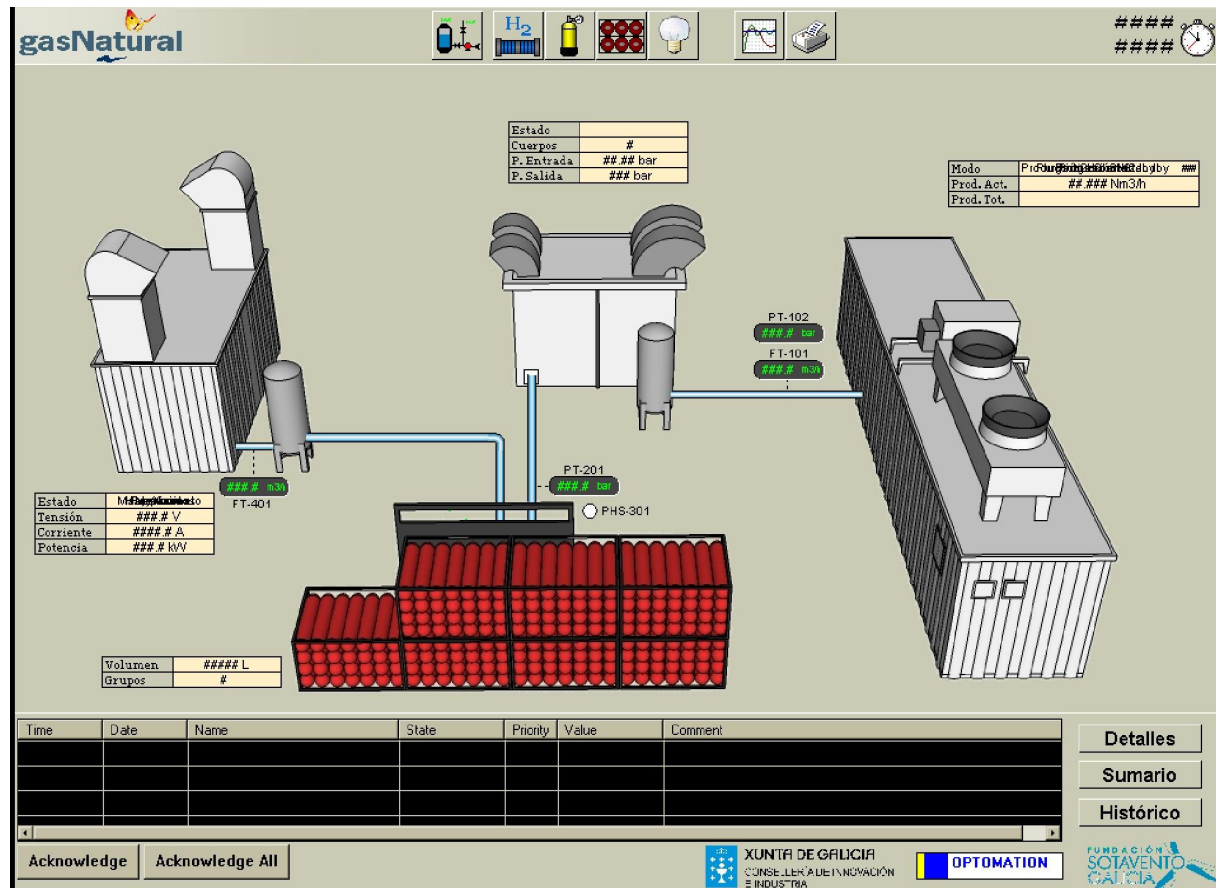


Figure 7: Main Screen control system.

Nowadays the installation is operating successfully in order to model the behaviour of each system component and integrate its operations, working with diverse wind generation scenarios and using different management strategies.

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